ANTARES Status Report

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Abstract

The ANTARES Collaboration is building a neutrino telescope 2400 m below the Mediterranean sea close to the Southern French coast. The site is already linked to the shore station by a 40 km-long electro-optical cable (EOC) which transmits power and data. A prototype line and an instrumentation line for monitoring environmental parameters have been successfully deployed and connected to the EOC via the junction box, using the IFREMER manned submarine. The Collaboration, after years of dedicated R&D and deployments of prototype lines, is now ready to deploy the detector starting in spring 2004.

1. The ANTARES neutrino telescope

The ANTARES (Astronomy with a Neutrino Telescope and Abyss environmental RESearch) project started in 1996 and involves physicists and engineers from France, Germany, Italy, Russia, Spain, The Netherlands and the United Kingdom. ANTARES aims to detect neutrinos with $E_\nu \gtrsim 10$ GeV in order to investigate ν astrophysics, dark matter in the form of weakly interacting massive particles (WIMPs), monopoles and ν oscillations. Cherenkov light produced by relativistic charged particles is detected by a 3D-array of optical modules (OMs), pressure resistant glass spheres containing phototubes (PMTs). Photon arrival times and PMT charge amplitudes allow track and energy reconstruction.

Current predictions and upper limits from previous generation and currently running telescopes indicate that the expected signal from cosmic neutrino sources require very large detectors to be observed. About 200 ν-induced upward-going muons/km^2/yr are expected for a diffuse flux from an isotropic distribution of optically-thin extra-galactic sources equal to the Waxman & Bahcall limit of $4.5 \cdot 10^{-8} E^{-2}$ GeV^{-1} cm^{-2} s^{-1} sr^{-1} [9]. Galactic source luminosities $\gtrsim 10^{35}$ erg/s, achievable in the presence of compact accelerators and intense magnetic fields, are required to produce a rate larger than 10 events/yr from 100 TeV neutrinos in a km^2 array. In 1 year of data-taking the ANTARES expected sensitivity will surpass that of current arrays and that expected for 600 live-days of AMANDA II [2]. The success of this experiment, with an effective area > 0.02 km^2 for $E_\nu > 10$ TeV

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and well reconstructed events, will be a milestone demonstrating the feasibility of an underwater km^3 detector in the Mediterranean, complementing a similar array in the South Polar ice. Two km^3-size detectors, one in each hemisphere, are needed to cover the whole sky (including the Galactic Centre which is not accessible from the South Pole using upward-going neutrinos), and guarantee a cross-check of systematic errors arising from different Cherenkov media properties.

The ANTARES site (42° 50'N, 6° 10'E) is well-shielded from the atmospheric muon background by 2400 m of sea water and has been selected after an intense program of sea campaigns dedicated to measurements of water transmission properties. The absorption length is about 60 m at 470 nm and mainly determines the size of the instrumented region and the PMT spacing. The effective scattering length * is more than 200 m, this is considerably larger and less depth dependent than that of ice. The optical background, which is absent in ice, is due to β decays of ^{40}K and to a continuous bioluminescence rate which combine to give a rate of about 60 kHz on a 10" PMT. Occasional, short bioluminescence bursts momentarily increase the rate up to MHz. These bursts induce a dead-time of 5% per PMT, however the detector dead-time from this source is far less due to the requirement for coincidences. The average light transmission loss of an OM due to bio-fouling and sedimentation is $< 2\%$ at its equator after 1 year from deployment, this saturates with time [1].

Twelve lines will be deployed each with 75 OMs mounted in 25 triplets (storeys). Each OM has a 10" Hamamatsu PMT [10] oriented at 45° from the vertical. Storey separation is 14.5 m giving a total implemented height of about 350 m which starts 100 m above the sea bed. Lines are kept taut by buoys and are at an average distance of $\sim$ 65 m from one another in an octagonal configuration. The production of the 900 OMs started in spring 2002. The readout of each PMT signal is shared by 2 Analog Ring Sampler ASICs which provide the analog signal time and charge digitization. The ARS implements a waveform (WF) shape-sensitive discrimination to distinguish single photoelectron-like pulse shapes (more than 98% of events) from larger pulses. Tests have shown that an overall time resolution of $\sim$ 1 ns can be achieved mainly limited by the transit time spread (TTS) of the PMTs [4]. The ARS's together with a compass and tilt meters or hydrophones for the line positioning are located inside a titanium container which is common to each storey. Considering a singles rate of 70 kHz from ^{40}K and bioluminescence rate of 2% of WF events, the typical data rate to shore will be $\sim$ 7 MB/s/PMT; a $\sim$ 100 PC farm on shore will process data. The DAQ system design is given in [3]. Time calibrations are critical for the ANTARES experiment: a system of LED and laser beacons and a clock calibration system [6] will allow a relative time precision between OMs of $\sim$ 0.5 ns and the absolute time will be

*Effective means that the scattered photon distribution, forward peaked in sea water, is accounted for.

determined with an accuracy of ~ 1 ms. The present planning indicates that the full detector will be installed by 2005.

From Nov. 1999 to June 2000 the Collaboration achieved a significant milestone in the deployment and operation of a "demonstrator line", instrumented with 7 PMTs at a depth of 1100 m and connected to shore with a 37 km-long EOC. The shape of the atmospheric muon zenith angular distribution was reproduced, despite the small number of PMTs and their 1D-layout. The ANTARES relative and absolute positioning acoustic system of rangemeters, compasses and tilt miters was tested. Relative distances and absolute positioning were measured with an accuracy of ~ 5 cm and of ~ 1 m, respectively.

In Oct. 2001, the 40 km-long EOC for power and data transmission between the detector and the shore station in La Seyne sur Mer was deployed. Since Dec. 9, 2002, the heart of the forthcoming array, the junction box (JB), has been in communication with the shore station. It was deployed during a sea operation requiring the dredging and lifting of 2.5 km of the undersea EOC. On March 17, 2003 the first data were received from a prototype detection line equipped with 15 OMs (5 storeys corresponding to 1/5 of an ANTARES line). The line was deployed in Dec. 2002 and connected in Mar. 2003 to the underwater JB using the Nautile manned submarine of the French IFREMER oceanographic research agency. During the same mission, the Nautile connected a prototype instrumentation line (deployed on Feb. 12, 2003) incorporating instrumentation to monitor underwater environmental parameters (a pulsed laser calibration system, a deep-sea Doppler current meter, detectors to measure sound velocity, salinity and water transparency). The success of the submarine connections has proved the viability of the final detector configuration with 12 line inter-connections radiating from the JB. Data are currently being acquired from PMTs, tilt meters and compasses of the prototype line and from the instrumentation line. They are consistent with the expected single counting rate of around 60 kHz due to ^{40}K β decays and peaks in excess of 250 kHz from bioluminescence bursts. The status and results of the prototype lines are described in [4]. Fig. 1 shows the layout of the future 12 line detector and underwater photographs of the prototype lines.

2. Expected physics performances

The ANTARES angular resolution is about 0.2° for $E_\nu > 10$ TeV, where pointing accuracy is not limited by the $\nu - \mu$ kinematics, but by the PMT TTS and by light scattering in water. The ANTARES sensitivity (90% c.l.) for point-like source searches to the upgoing μ flux induced by a typical E^{-2} differential ν flux is in the range between $4 \div 50 \cdot 10^{-16}$ cm^{-2} s^{-1} after 1 yr. Search strategies and discovery potential are discussed in [5]. The energy resolution and methods to reconstruct muon energy and parent neutrino spectra are discussed in [7]. The sensitivity (90% c.l.) to E^{-2} diffuse differential neutrino fluxes achieved by

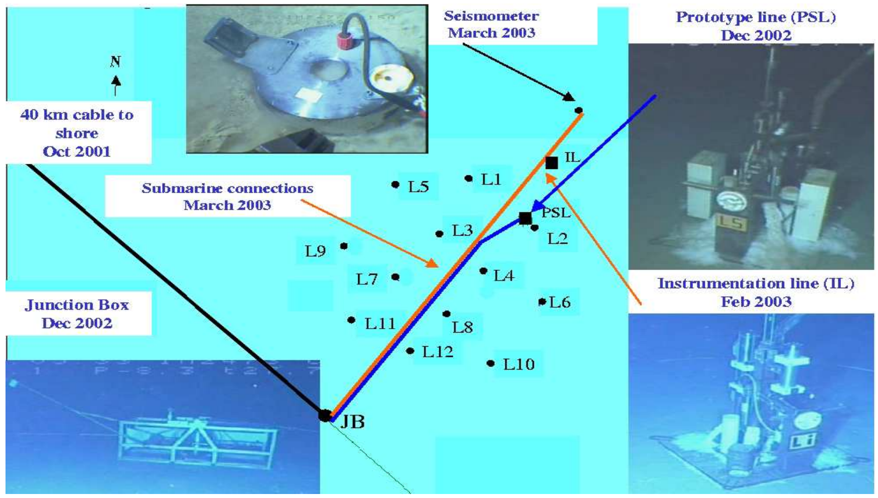

Fig. 1. The ANTARES layout: the positions of the deployed prototype lines (squares, PSL = Prototype Sector Line and IL = Instrumentation Line), the cables connecting them to the JB, the 40 km EOC and the future 12 lines are indicated. Underwater photographs of the 2 lines, JB and seismometer are shown.

rejecting the background with an energy cut of $E_\mu \geq 50$ GeV is $8 \cdot 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}. The sensitivity of ANTARES in the search of WIMPs is given in [8]. The upper limit on ν-induced muon fluxes (90% c.l.) from neutralino annihilation in the Sun is at the level of 400 km^{-2} yr^{-1} for $m_\chi \gtrsim 200$ GeV.

3. References

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